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The "Arms of the Physicist": Volta and Scientific Instruments

1. Introduction

Scientific instruments played a role of paramount importance in Alessandro Volta's prolific experimental work. The inventor of the electrophorus, the spark eudiometer and the electric battery was certainly a skilful experimentalist. Unfortunately, until a few years ago, most of Volta's apparatus was preserved as museum curiosities rather than essential material evidence for a better understanding of his scientific achievements. In spite of the fact that, for about thirty years, Volta was responsible for the physics cabinet of Pavia University, very little is known about his role in creating this important physics collection. Careful study of Volta's published correspondence as well as the recent discovery of a couple of detailed inventories of the cabinet,[1] allow us to cast new light on its evolution, on the instrument trade and on the relationships between Volta and the Italian and foreign makers who supplied the instruments. Furthermore, the study of the scientific apparatus, which is preserved in the Museo per la Storia dell'Università di Pavia,[2] together with analysis of the above mentioned documents, enabled us to distinguish between the apparatus which was purchased by Volta for his laboratory and the items which were in the collection before his arrival in Pavia.

Because of their peculiar history, the pieces of scientific apparatus which are related to Volta's activities can be broadly divided into two main groups. The first

[1] We would like to thank Dr. Alessandra Ferraresi, who found these inventories and kindly attracted our attention to them. She is currently working on these inventories for publication and constantly collaborating with us in the frame of our research concerning the history of the University and its scientific cabinets.

[2] The Museo per la Storia dell'Università di Pavia is located in the main building of the University. It is divided in two sections: one is dedicated to medical science, while the other preserves the collection of physics instruments. The latter collection, which numbers about 800 instruments, covering the period of time between 1750 and 1930 circa, has been restored, catalogued and studied starting in 1981.

includes the instruments which were invented, modified or used by Volta himself for his original investigations. The second concerns the teaching or research apparatus utilised by Volta in his physics courses and lecture demonstrations at Pavia University. If Volta's original instruments were always considered to be an important part of his "glorious heritage", the latter never attracted any particular attention. Finally their story is a "tale of two cities": Pavia and Como, where today the two main groups of apparatus are still preserved.

2. Volta's Original Apparatus and the Volta Temple in Como

The original scientific instruments of Alessandro Volta, one of the founding fathers of modern electricity as well as a celebrated and emblematic hero of Italian science, have been considered precious relics since his death. Like the religious relics (the often fake bits and pieces of the bodies of the saints), which maintained a halo of holiness, they were preserved, exhibited and admired as tangible evidence of his great work. Therefore the apparatus was more glorified than studied, and remained sealed in a spectacular and impressive temple. But we must start from the beginning.

After Volta's death in 1827, some of his apparatus was kept in Pavia, while several other instruments remained in the hands of his family.[3] In 1859 the Regio Istituto Lombardo di Scienze e Lettere in Milan, began to be interested in the fate of an important group of Volta's instruments and manuscripts, which at the time still belonged to his heirs and risked being dispersed. [4] After having charged a special committee to determine the size and importance of this heritage, the Istituto decided to acquire it. Unfortunately, dealing with the family proved to be quite difficult, and only in 1861 did the Istituto advertise a public subscription for collecting the sum of 100,000 lire, which was necessary to buy the lot from Volta's heirs. (Another important group of Volta's apparatus was preserved at Pavia University). This huge amount of money was collected only with substantial help from the city of Como (20,000 lire) and a final contribution from the government (26,000 lire). Finally in 1864 the Istituto was able to open a special exhibition room (Sala dei Cimelii), where the acquired instruments and manuscripts of Volta were displayed.

In 1899 the town of Como organised an important exhibition for the first centenary of the invention of the electric battery. The exhibition was dedicated to the electrical and silk industries, which were particularly important in this part of

[3] It is very difficult to understand whether some of these instruments were originally made or acquired for the cabinet of Pavia University. Very often in the past the division line between the apparatus belonging to a private collection of a scientist and the apparatus which he ordered for a University collection was very unclear. Certainly Volta, who was the most important and celebrated Italian scientist, would not have had any problem in keeping some of the instruments which he had used in the cabinet of Pavia before his retirement.

[4] See FERRINI (1899).

Lombardy. A special pavilion was dedicated to Volta's work and instruments, which were borrowed from the Istituto Lombardo, Pavia University and various other institutions and collections. Unfortunately (and ironically) a few week after the official opening, a short circuit (or an overheated cable?) in the electric system of the exhibition, which was supposed to celebrate the triumph of electricity, caused a disastrous fire. In about 45 minutes the industrial pavilions were destroyed and among them the one with Volta's relics.[5] The exhibition was rapidly reconstructed on a smaller scale, but the ancient instruments were lost forever. Sadly, only a few fragments of molten brass and glass were extracted from the ashes and preserved as "relics of the relics".[6] But like the mythical phoenix, the instruments would be born again from their ashes. In 1927 the centenary of Volta's death, thanks to the ideas, the efforts and the impressive financial support of Francesco Somaini (1855-1939) a wealthy industrialist of Como, the spectacular Tempio Voltiano was opened near Lake Como. Temple and not museum. In fact, the building is a neoclassic-style temple made of concrete but lavishly decorated with coloured marble, columns and stucco work, which glorifies Volta as the deus ex-machina of the electrical age. The intention to sanctify Volta was clear: "tempio in cui il culto di Volta è solennemente celebrato".[7] In this period of ebullient nationalism during Mussolini's regime, the figure of Volta (as well as of several other Italian scientists and inventors) was taken as an example of the Italian genius for reaffirming the idea of a pretended intellectual superiority and for consolidating the image of fragile national cohesion.[8] But Somaini (who was not really involved in this kind of propaganda and was sincerely moved by his limitless admiration for Volta) not only provided a spectacular memorial building, he also desired to reconstruct the lost instruments. Thanks to the work of a team of scientists and skilled craftsmen, it was possible to produce a large number of replicas, which, together with a few surviving original pieces of apparatus, were displayed in the temple.[9] In fact most of Volta's original apparatus was not sophisticated precision instruments, but had been quite crudely manufactured by his local instrument maker. Even the measuring apparatus such as the famous electrometers, which played such an important role in his research, were very simple with their scale hand-written on a strip of paper! Therefore, the craftsmen of the first quarter of the 20th century could easily reproduce them by carefully copying existing engravings and photographs of the originals and by using the same materials. Furthermore, some of the people who were involved in this

[5] Fortunately Volta's papers did not get lost, because of the decision to keep all the manuscripts of the collection in the Istituto Lombardo.
[6] See POGGI (1899). Poggi in this work, which was published just after the exhibition, made a pathetic description of all the rest of the instruments, which had been extracted from the ashes.
[7] See ALIATI (1945), p. 195.
[8] See PANCALDI (1995).
[9] Both the original apparatus, as well as the replicas, belong today to the Tempio Voltiano.

project, knew the original instruments well, having had the opportunity to handle them before the fire of 1899.

The replicas are so well made that they are practically indistinguishable from Volta's originals. The replicated apparatus and the originals can be distinguished only by a special lead seal attached to the latter. Today in Volta's temple there are more than 200 instruments. Less than 100 are original while the others were made in the 1920s.[10]

That, in short, is the story of the collection of Volta's research apparatus preserved in Como. But again, we have to point out that, in spite of their importance and their dramatic fate, Volta's instruments were never carefully studied as material witnesses of the history of science but were venerated as "mirabili cimeli del Sommo fisico".

3. Volta and the Physics Cabinet of Pavia University

Alessandro Volta was at the University of Pavia between 1778 and 1819 and under his direction the evolution of the physics cabinet was very important. Not only was the number of instruments largely increased, but also the typology of the collection changed. Under Volta's direction the physics cabinet began its transformation into a physics laboratory. Since 1932 most of the historical apparatus of the University has been kept in the Museo per la Storia dell'Università, which also houses an impressive collection of anatomical specimens and medical apparatus. Unfortunately, until the beginning of the 1980s, the about 800 physical instruments from the 18th and 19th centuries did not arouse any particular interest. They were almost forgotten and were sadly deteriorating in a corner of the University museum. Nobody really cared about them. But in the last 17 years thanks to the activities of the members of the "team of history and teaching of physics" of the University and to the support of the directors of the Museum, the collection has been carefully restored and redisplayed.[11] Moreover, the instruments have been catalogued and studied, and the collection is now regularly open to the public. The re-organising of the instruments and the discovery of several documents (including two ancient inventories of the physics cabinet) naturally increased interest in the history of the collection. Thanks to these materials, it was possible to begin to write a detailed account of the evolution of the collection, to better understand the fundamental role of Volta in organising the cabinet, as well as correcting a wrong tradition which referred to "Volta relics" as only a few pieces of electrical apparatus. Not only did these so-called relics give a wrong and very restricted idea of Volta's equipment in Pavia, but they also included instruments which had been proposed by Giuseppe Belli (1791-1860), well after the death of Volta.

[10] See *Il Tempio Voltiano in Como*, Como: Cavalleri, 1940 [reprint 1973].
[11] BRENNI (1983); BELLODI (1991), also published in BELLODI (1991a). See also: BELLODI (1991b) and BELLODI (1993).

The University of Pavia has a very long tradition. In 825 the Frank king Lotario founded the first school of rhetoric in this city, the capital of his kingdom. This school was supposed to train the administrators of Lotario's kingdom and is often considered the origin of the future University. However, in 1361 on the suggestion of Galeazzo II Visconti, Lord of Pavia, the German emperor Carlo IV established the statute of the "Studium Generale", thus founding one of the first European universities. But in spite of its very long tradition, Pavia University did not shine with a particularly brilliant light until the second half of the18th century. The arrival of Volta in Pavia was emblematic of a period of profound renewal in this institution. Thanks to the study reform started by Empress Maria Theresa of Austria (1717-1780) and continued by her son Joseph II (1741-1790), the University of Pavia entered a new and very fruitful era of its history.[12] The Austrian rulers, who wanted to create a great Italian University which could compete with the best in Europe, did not spare money or effort in transforming a sleeping institution into a very important, active cultural centre. Around 1770 a new library was founded, a magnificent reading room was erected and at the same time the botanical garden was created. The cabinet of physics was opened in 1771.[13]

In the late 18th century the use of experimental demonstrations during natural philosophy courses was well rooted in Europe.[14] Thanks to the work of several lecturer-demonstrators such as Winston, Ferguson, or Desaguliers in England, Musschenbroek and 'sGravesande in Holland and Nollet in France (to mention just a few of the most important names), the amount of demonstration and teaching apparatus which was available was impressive. Their treatises on physics were very successful and they were well known by the experimentalists of the time. A few important collections of apparatus and models of machines were also built up in Italy. Among the most famous are the collection of Giovanni Poleni (1683-1761) at the University of Padua, inaugurated in 1740,[15] and Carlo Alfonso Guadagni's (?-1795) collection at the University of Pisa.

The first director of the cabinet of Pavia was the Piarist father Carlo Barletti (1735-1800) from Piedmont, who was appointed professor of experimental physics

[12] See MONTI (1996); see also GALEOTTI (1978).

[13] Milan, the capital of Lombardy, could not have a University, but here the Austrian government supported the development of other scientific institutions such as the astronomical observatory of Brera and the botanical garden.

[14] See BRENNI (1996).

[15] See PANCINO and SALANDIN (1987) and *Il teatro di filosofia sperimentale di Giovanni Poleni: mostra di strumenti scientifici: Padova, Palazzo della Ragione, 15 marzo-27 aprile 1986*, a cura dell'Università degli studi di Padova; Accademia patavina di scienze, lettere ed arti; Comune di Padova, Assessorato beni culturali; Provincia di Padova, Assessorato pubblica istruzione, Trieste: LINT, 1986.

at the University at the end of 1772.[16] On his arrival, Barletti found a very poor collection, whose instruments were in a sad state of conservation. In 1773, he stayed a month in Florence, where the new and magnificent cabinet of the Grand Duke of Tuscany greatly impressed him. This visit, as well as the meetings with Felice Fontana (1730-1805), certainly stimulated Barletti, both in his studies and in his project of reorganising the University cabinet.[17] In fact it was probably around 1775 that a series of instruments, which had been used by Guadagni in Pisa, arrived in Pavia. With the help of the local instrument maker Giuseppe Re (?-1820) and the factotum-assistant Carlo Guarnaschelli, Barletti was able to set up the physics cabinet, where the instruments were kept and where the experiments were performed. From a first inventory[18] of 1776, we can see that the collection was composed of about 200 pieces of apparatus from the simplest "glass vessel" to the most sophisticated pneumatic pump. From this inventory we have gleaned some information concerning the provenance of several pieces of this first core collection:

- 30 pieces of apparatus were defined as "old" and "remains" of the University. They probably existed there before the creation of the physics cabinet.
- 54 were mentioned as "new". They probably came into the Pavia cabinet after 1773.
- 34 pieces came from the famous English lecturer-demonstrator and instrument maker Benjamin Martin. Most of these were pneumatic instruments and accessories for pneumatic experiments.[19]
- 22 pieces of optical apparatus came from the instrument maker Selva[20] of Venice. It is impossible to say if they were really made by him or simply retailed.
- 6 permanent magnets were purchased in Florence and mounted in Pavia by Giuseppe Re.

[16] See LAGUZZI (1994).

[17] See CONTARDI (1996). We thank Simone Contardi for his help and for his useful suggestions concerning this article.

[18] See BARLETTI and GUARNASCHELLI and RE (1776).

[19] It is well known that, like many of his colleagues, Benjamin Martin was maker as well as retailer of instruments. Thus, not all the apparatus mentioned in the inventories as *Macchine da Londra di Beniamino Martin* had been made by him. See MILLBURN (1976) and MILLBURN (1986).

[20] The Selva family, which originated from Friuli, had been established in Venice since the second decade of the 18th century. The first optician and glass maker was Domenico (?-1758). His son Lorenzo (1716-1800) learned the skills of the art with him and continued his tradition. The Selvas made several microscopes, telescopes and other "dioptric and catoptric" instruments. Their instruments are not always signed and, we know that Lorenzo sometimes signed his apparatus with his father's name. Therefore precise attribution and dating of their instruments is not always possible. See Alberto Lualdi, "La famiglia Selva, ottici del '700 veneziano", forthcoming in *Nuncius*. We thank Dr. Lualdi of the University of Pavia for providing this information.

• 12 instruments (mechanical models and demonstration apparatus) came from a certain Zanatta of Turin.

When Volta was appointed professor of experimental physics at Pavia University,[21] at the end of 1778, he was a rising star in the European scientific firmament. His research and his inventions (the electrophorus, the electric pistol) were well known to the scientific community. On Volta's arrival in Pavia, the teaching of physics was divided into two distinct and separated branches, which were common at the time. Barletti became responsible for *Fisica classica o generale*, while Volta had to teach *Fisica sperimentale o particolare*. The former included statics, dynamics, hydrostatics, hydraulics and astronomical physics, which formed the more mathematised part of physics. The latter, dealing with phenomena concerning electricity, magnetism, heat, pneumatics, acoustics, meteorology and optics was more phenomenological and experimental.

Before arriving in Pavia, Volta had been *reggente* (director) and later also professor of physics at the colleges in Como, where he clearly demonstrated his interest in creating a good cabinet of scientific instruments.[22] Volta was very conscious of the importance that scientific apparatus had in his activity, and in 1778 Count Luigi Lambertenghi (1739-1813) reported that he had defined such apparatus as "les bras des Physiciens" (the physicists' arms).[23]

This interest was enhanced in Pavia where Volta spent a large amount of his time and energy, for almost thirty years, and profited from all his scientific and political influence in building up a major physics cabinet. His ambitions concerning its development appear clearly in a letter of March 18, 1779 addressed to Count Firmian:[24]

> Io per mia parte non mancherò di promoverne l'ingrandimento, e sol che la Corte e il Real Governo mi secondi, in termine di pochi anni spero di poter in guisa completare il gabinetto di Fisica, che nulla manchi all'istruzione de' Giovani e alla curiosità de' Forestieri e faccia l'ammirazione di tutti.[25]

[21] On the history of the University of Pavia, see VACCARI (1982).
[22] About Volta's effort to equip a physics cabinet in Como, see *VE*, I, 120, pp. 104-5; 144, pp.127-30; 221, pp. 207-8 and Appendix V, "Articoli relativi ai bisogni delle Regie scuole di Como", pp. 471-3.
[23] *VE*, I, 273, p. 277.
[24] *VE*, I, 322, pp. 331-2. Carlo Count of Firmian (1716-1782) was a member of a noble Tyrolean family. After having studied in Austria and later in Leyden he returned to Austria where he began a political career. Under Maria Theresa he first became plenipotentiary governor in Naples and from 1758 onward in Lombardy. For more than 20 years Firmian, a man with several cultural interests, remained one of the most important political correspondent of Volta. While always very careful in following the instructions coming from Vienna, Firmian represented one of the most important links between the capital of the Austrian Empire and Lombardy.
[25] *VE*, I, 322, p. 331.

In fact, during the summer of 1779, in a couple of letters to Firmian, Volta explained how the collection of the University was poorly equipped as far as mechanics, hydrostatics, optics and electricity were concerned, while he was quite satisfied with the pneumatics apparatus. Furthermore, he prepared for Firmian a first list of the instruments he needed.[26] Firmian was sincerely interested in supporting Volta's request but asked for more details concerning the prices of the instruments.[27] The list was subsequently modified and refined.

Before following the evolution of the cabinet and retracing Volta's acquisition policy for the collection, it is necessary to write a few words about the instrument-making industry at the time. It is well known that during the 18th and for most of the 19th century the production of scientific and precision apparatus in Italy was quite poor. The several reasons for this disappointing "state of the art" have been studied and analysed elsewhere.[28] There were very few talented instrument makers and most of them worked as "mechanics" for the universities or for the astronomical observatories. In general they were badly equipped and worked alone or with a few apprentices. They were only partially able to supply a limited, local market with relatively simple physical, optical or mechanical demonstration apparatus. It was almost impossible to find in Italy a real "precision maker", who was able to manufacture sophisticated astronomical or optical instruments. Therefore almost all the best instruments which could be found in the Italian scientific collections of the time were acquired abroad. The centre of excellence for the production of scientific apparatus at the time was London, where some of the most ingenious and skilful instrument makers of the time such as Ramsden, Dollond, Cary, Nairne and Adams were active.[29] Several of these makers had been able to develop large and extremely well equipped workshops, whose size and production would have been absolutely unthinkable in Italy. Paris was another important centre for the production of scientific instruments. Although the Parisian makers could hardly compete with their English counterparts as far as quality and quantity of produced instruments was concerned, nevertheless the production there was significant. For example, as far as experimental physics was concerned, Nollet and subsequently Sigaud de la Fond had organised a network of craftsmen who were able to manufacture the demonstration apparatus which they had described in their treatises. These pieces of apparatus, which were lavishly decorated, were very much appreciated by the wealthy amateurs of science, who had their own scientific cabinets.[30]

[26] *VE*, I, 334, pp. 348-50 and *VE*, I, 342, pp. 359-60.
[27] *VE*, I, 343, p. 361.
[28] See BRENNI (1985).
[29] Much has been written about English scientific instrument makers and their trade. The fundamental work of Gloria Clifton gives an excellent survey of them as well as a rich bibliography: CLIFTON (1995).
[30] About European scientific instruments and their makers in the 18th century, see DAUMAS (1953) and TURNER (1987).

It is not surprising that many instruments which Volta would have liked to acquire for his cabinet had to be ordered in London and in Paris. During the second half of 1779 Volta exchanged many letters with his correspondents in the two cities to gain more information about the apparatus and the prices. As far as instruments were concerned, his contact in London was Jean Hyacinthe de Magellan (1722-1790), a Portuguese instrument maker and physicist living in London. The role of Magellan in the diffusion of scientific novelty and instrumental know-how in Europe is well known[31] and G. Turner perfectly defined him as "busy gossip and unofficial London agent for continental science".[32] Magellan, who had provided apparatus since the time Volta was in Como,[33] knew all the most important makers in London and at the same time was always extremely well informed about the newest instruments and machines. In Pavia, Volta greatly profited from his connection with Magellan. Following a request from Volta, in a letter of September 1779, Magellan gives information, suggestions and prices related to several instruments such as the newly invented Atwood machine,[34] an orrery with a tellurian, several microscopes (solar and compound microscopes, as well as a Lyonet-type microscope), 'sGravesande optical boxes, and a series of lenses and burning mirrors, etc.[35] And again, in December of the same year, Magellan, who had given commissions to the makers for some of the instruments, gave more details about them and asked for more information concerning Volta's preferences about the decorative details and the materials of the various instruments.[36] The Atwood machine and the orrery were commissioned from George Adams. Adams and Benjamin Martin provided a few microscopes, while Magellan inquired of Samuel Parker about the possibility of having a large burning lens. At the same time he asked for money for the makers. Normally the government sent the money to their financial agents, the brothers Songa, while the banker Caccia paid for the apparatus made in Paris.

As far as French instrument were concerned, Volta was corresponding with Barbier de Tinan (?-1791)[37] who was in contact with the physicist Rouland (active in the 1770s and 1780s). Rouland was the nephew and representative of Jean René Sigaud de la Fond (1730-1810) and from about 1775 he was the director of Sigaud's business. In

[31] See MALAQUIAS and THOMAZ (1994).
[32] See LEVERE and TURNER (1973), p. 50.
[33] *VE*, I, 297, pp. 300-2.
[34] In 1780 Magellan had been the first to publish a description of the famous falling machine, which had been proposed by G. Atwood. In a letter of 9 April 1779 Magellan mentioned the instrument to Volta. See *VE*, I, 327, pp. 338-40.
[35] *VE*, 354, pp. 377-9.
[36] *VE*, 365, pp. 387-90.
[37] Jean Jacques Théodore Barbier de Tinan was "commissaire de la guerre" in Strasbourg. He was interested in scientific matters and, in an article to the Royal Academy of Science, he proposed installing a lightning protection on the cathedral of this town.

fact a large set of instruments were purchased in Paris from Sigaud de la Fond. Sigaud, was the successor of Nollet at the Collège Louis le Grand in Paris, he wrote several works including the very famous *Description et usage d'un cabinet de physique expérimentale* of 1775, which became a standard treatise for the continental experimentalists. In this treatise Sigaud illustrated and described most of the instruments which were common in the cabinets of the last quarter of the 18th century. Most of Sigaud's apparatus was similar to the equipment described by Nollet a few years earlier. His instruments, which were elegant, painted and richly decorated to match the aesthetic taste of French collectors and amateurs, were more often appreciated as *objets de salon* for demonstration, than used as precision instruments. The trade of instrument makers in Paris was quite different than in London. In fact Sigaud and Rouland after him were not really makers but, like Nollet, directed and supervised a series of craftsmen who constructed instruments for them and their clients. One of the first orders to Barbier de Tinan was sent in 1779. The instruments ordered in Paris for Pavia were mechanical and hydraulic demonstration apparatus (centrifugal machine, percussion and parabolic trajectory instruments, etc.) as well as models of simple machines (levers, pulleys, Archimedean screw, capstan, etc.). Rouland's letter from the beginning of 1781 was reassuring: "c'est moi seul qui préside depuis plus de 4 ans à la construction de tous nos instruments. J'y mis toute le diligence et toute l'exactitude dont je suis capable".[38]

Nevertheless, if English instruments were universally admired, French ones were not always appreciated.

For example, at the end of 1779 Count Luigi Lambertenghi gave Volta his advice for the future, in relation to new equipment for the cabinet:

> In generale io preferisco sempre alle macchine francesi quelle fabbricate in Londra, perchè di solito più eleganti e più esatte. Benchè siavi in queste il più caro prezzo che ritiene dal farne acquisto, sono sempre preferibili per un pubblico stabilimento dove l'eleganza merita un riguardo particolare. Io poi mi fido poco del Sigaud De La Fond laborioso, ma per quanto ho sentito dire egualmente poco esatto costruttore, ossia direttore de' costruttori di macchine, che mediocre Fisico.[39]

It is interesting to note that Lambertenghi's attitude was shared by several physicists of the time.

On January 7, 1780 Volta, who by that time had collected more precise information, sent Firmian a new corrected list of apparatus and machines. In the same letter Volta pointed out, that several machines could be made in Pavia or in Milan and he complained about the small number of artisans who were actually

[38] *VE*, II, 418, p. 22.
[39] *VE*, I, 360, p. 384.

working locally.[40] The list had to be corrected once more before being submitted to Prince Kaunitz in Vienna.[41] Finally, Firmian, in a letter to Volta dated May 6, confirmed that the government had agreed to acquire the desired apparatus.[42] In August Barbier de Tinan stated that Rouland had assured him that the first of Sigaud's machines were ready and would be sent during the same month (but in fact they were shipped later). In November Magellan informed Volta that some of his apparatus was almost ready[43] and in December he wrote that finally six cases of instruments were being shipped to Genoa.[44] Finally, in March 1781, Volta got the first 5 cases of apparatus from Paris.[45] He was satisfied with them: "le ho trovate molto ben costrutte, ed eleganti nella massima parte"[46] but he had the unpleasant surprise of seeing that the glass elements of three models of pumps were broken. New glasses had to be ordered in Venice as there was no glass factory near Pavia. Volta therefore recommended Rouland to be more careful with the packing of instruments. In fact, the transportation of instruments from Paris and London to Italy was a risky business. The instruments after having been partially dismantled were packed in big wooden cases, but, in spite of these precautions, accidents were not uncommon. It is easy to imagine the vibration and the bumps experienced by these cases, as they were loaded and unloaded from horse carriages travelling for hundreds of miles, or being badly shaken on board a ship in rough seas. Finally, in March 1781, the shipment from London also arrived in Genoa[47] and Volta, who had been absent from the University, found it in Pavia at the beginning of May.[48] Again the apparatus had been damaged in transit. The glasses protecting the orreries were smashed and the instruments had to be completely taken apart to remove glass splinters from the mechanism. Apart from this annoying accident, Volta was extremely satisfied with the English instruments: "tutti poi sono di una perfezione e bellezza sorprendente". Volta tried to communicate his enthusiasm to Firmian by describing the perfect workings of his new Atwood's machine:[49]

[40] *VE*, I, 368, pp. 394-5 and *VE*, II, Appendix IX, "Nota di macchine singolari ed anche di lusso", pp. 455-67.
[41] *VE*, I, 378, pp. 404-5. Wenzel Anton Kaunitz-Rietberg (1711-1794) descendent of a noble Moravian family, was an important Austrian politician. Ambassador in Turin and then in Paris. In 1753 he became chancellor and, for about 40 years, he directed the foreign policy of the Austrian Empire.
[42] *VE*, I, 379, pp. 405-6.
[43] *VE*, II, 410, pp. 14-5.
[44] *VE*, II, 413, p. 17.
[45] *VE*, II, 421, pp. 25-6.
[46] *Ibid*., p. 25.
[47] *VE*, II, 427, pp. 31-3.
[48] *VE*, II, 429, pp. 34-6.
[49] Volta got the third Atwood machine ever made. Probably the first one was in the hands of its inventor, while the second one was sent to Portugal. See MALAQUIAS and THOMAZ (1994).

> Le leggi della caduta dei gravi sono messe così chiaramente e distintamente sott'occhio, che anche chi non conoscesse nulla della teoria, vi è tosto condotto e le intende a meraviglia. Da qualche giorno che ho messo alla prova la Macchina non so quasi occuparmi di altro, tanta è la soddisfazione.[50]

Firmian, on his side, proposed sending Saruggia to Pavia for the repairs, but Volta did not consider Saruggia's work necessary: Re was able to restore the damaged apparatus alone. (But he also asked Firmian for exceptional financial help for covering the extra work of his instrument maker).[51] At the same time, Volta was informed of another shipment which had arrived in Genoa and of other instruments on the way from Paris.[52]

From the beginning of the 1780s the physics cabinet of Pavia University became a very attractive and fashionable place to visit. Italian and foreign visitors flocked to the University desiring to see the apparatus of the cabinet, and to follow Volta's experiments and explanations. Volta tried to satisfy their curiosity but the reception of the guests was a time and energy-consuming exercise:

> Da quindici e più giorni sono occupato più ore al giorno a servire forastieri la maggior parte di distinzione, che vogliono vedere il Gabinetto di Macchine, e intenderne da me la descrizione, ed essere al fatto di molte sperienze. Io non mi rifiuto di servirli, benchè la fatica sia grande, e non mi rifiuterò finchè sia tollerabile; ma ormai parmi che troppo cresca in questa stagione soprattutto, in cui abbiamo e Lauree ed esami, oltre le ordinarie lezioni.[53]

In the years 1781 and 1782, Volta travelled extensively in Europe visiting some of the most important cities in Switzerland, Germany, the Netherlands, France, England and Austria. During this trip Volta spent a few months in Paris and several weeks in London. Of course, he had the opportunity to meet some of the leading members of the scientific community. He profited by visiting a large number of important scientific collections, as well as several astronomical observatories. The long European trip also gave Volta an opportunity to add to the equipment of his cabinet. In February 1782 he was in Paris and he proposed to Count Firmian that a new series of instruments should be acquired: "or dunque non dovrò provvedere di questi stromenti il Gabinetto di Pavia, farli costruire qui a Parigi, dove c'è tutto il comodo, e portarli meco al ritorno?".[54] However, the government officials were not at all satisfied with the French instruments and they pressured Volta to buy only from the London makers. On March 2, Giovan Battista Bovara (1734-1812), who was an important government official wrote:

[50] *VE*, II, 429, p. 36.
[51] *VE*, II, 438, pp. 43-4.
[52] *VE*, II, 432, pp. 37-8.
[53] *VE*, II, 436, p. 41.
[54] *VE*, II, 470, p. 84.

> Le Macchine di Parigi sono molto mediocri, e di più hanno sofferto essenzialmente nel viaggio, epperò il Governo le farà sapere di sospendere qui le ulteriori provviste. Quelle di Londra sono bellissime, eleganti, ed arrivate in ottimo stato. Per questa ragione il Governo ha determinato di spendere a Londra la precitata somma.[55]

Three days later a letter from Count Firmian repeated the same suggestion, which was in fact an order:

> Per rapporto alle Macchine, che vorrebbe V.S. Ill.ma far travagliare a Parigi io La devo prevenire che le ultime tre grosse Casse spedite da M.r Sigaud, sono arrivate in molto cattivo stato; e che la loro costruzione non è delle più eleganti, in modo, che forse meglio si potrebbe lavorare in Paese; epperò potrà Ella sospendere gli Ordini o per acquistare, o per costruirne delle ulteriori.
> Altrettanto belle, e degne del Gabinetto di Fisica sono le Macchine pervenute da Londra; onde io scriverò a' SS.ri Songa, di pagare a V.S. Ill.ma 100. Zecchini de' quali si potrà valere per alcune relative provviste; e siccome ho osservato che nel Gabinetto di Pavia manca specialmente il Corredo per l'Idrostatica, Scienza tanto necessaria, e vantaggiosa a questo Stato, che abbonda di acque; così dovrà aver cura di provvedere quelle macchine, che più convengono alle dimostrazioni di questo così interessante oggetto.[56]

And in fact, Volta profiting from his stay in London, ordered a series of new instruments from the best local makers, which Magellan promised to send to his friend and colleague. Magellan always preferred shipping the instrument to Genoa instead of arranging land transport. This was because it was possible to insure the ship as well as its goods and in the event of accident (pirate or wreck) the money for the merchandise was not lost. In 1783 the Swedish ship "Dama Bianca", which was also transporting three cases full of instruments, which had been recently ordered by Volta during his last trip to London, was unfortunately captured by the Spanish.[57] These accidents were actually not so unusual. In 1779 Lord Cowper lost an electric pistol made by Nairne in London, because the English ship which was transporting it was captured by the French navy.[58] In spite of the efforts of Volta and the Austrian government, which immediately contacted the Spanish government, the situation could not be solved until 1785,[59] when the ship was released and the cases of instruments finally arrived in Pavia! This event caused a lot of trouble, not only because of the inevitable delay but also because of the long exchange of letters concerning the insurance.

In 1784 Volta undertook another long trip in Europe and visited several cities including Prague, Leipzig, Dresden, Berlin, Vienna and Paris, but before leaving

[55] *VE*, II, 473, p. 89.
[56] *VE*, II, 475, pp. 91-2.
[57] *VE*, II, 525, pp. 148-50; 636, pp. 283-5.
[58] *VE*, I, 325, pp. 335-6.
[59] *VE*, II, 661, pp. 310-1.

Pavia he wrote a report to Prince Kaunitz concerning his cabinet.[60] First, he badly needed a proper Physics Theatre:

> Manca alla Fisica il teatro per le pubbliche esperienze, le quali si fanno ora dal Professore nella sala delle macchine, che pur non basta a tutte contenerle [...]. Annesso al teatro fisico od alla Sala delle macchine ci vorrebbe una stanza come bottega, ossia stanza dove tenere le lime, seghe, martelli, ed altri utensilj necessarj per l'istantanea riparazione e accomodamento delle macchine.

Then he proposed a long list of instruments to acquire in London, Paris, Geneva and Vienna, including a circular dividing engine, a hydrostatic balance, a magnetometer, a pyrometer, a Zimmermann water compression machine, several of Saussure's hygrometers and one of his magnetometers, a large battery of Leyden jars, several pieces of glassware from Bohemia and many other instruments. Among the machines, Volta proposed an expensive model of Watt's steam engine (100 guineas!):

> Sarebbe però questa una superba macchina, unica in Italia, e di grande ornamento al Gabinetto di Pavia, se non anche di molta utilità potendosi forse arrivare a costruire su quel modello anche da noi.

Then Volta visited Vienna, where he was treated with honour. Volta recounted his trip to Count Johann Joseph Wilzeck (1738-?).[61] The Austrian Government was very supportive of him, and not only was Volta given several pieces of apparatus (glassware, microscopes, a battery of Leyden jars and an important quantity of mercury for his experiments) but also something that was and still is the dream of every scientist: he was offered the possibility to invest an almost unlimited amount of money in his cabinet: "inoltre mi è stata data facoltà di fare provvista, dovunque ne incontrassi nel seguito del viaggio, di buoni istromenti di Fisica, per una somma indeterminata, a mia discrezione".[62] Volta of course profited from this beautiful opportunity and proudly described his new acquisitions to Wilzeck.

In January 1785, the first project of the physics theatre was ready.[63] At the same time, Volta wrote to Adams and Magellan asking for more information concerning the prices of various new instruments which had to be ordered. Then, while the instruments acquired in Austria and Germany were arriving at the University, he suggested that several simpler instruments could be made in Pavia or Milan by the local makers and for a lesser price (see below).[64] In March, Volta examined the plans

[60] *VE*, II, 584a, pp.217-20.
[61] *VE*, II, 608, pp. 245-9. Count Wilzeck was the successor of Firmian in Milan as Austrian plenipotentiary minister in Lombardy.
[62] *VE*, II, 608, pp. 247.
[63] *VE*, II, 635, pp. 281-2. The physics cabinet had been relocated before 1779. See *VE*, I, 333, p. 348 and *VE*, I, 334, pp. 348-50.
[64] *VE*, II, 636, pp. 283-5.

for the physics theatre and expressed his doubts and suggestions to Wilzeck. For example, he desired a larger area for the public as well as for the largest apparatus. He suggested copying the "theatre" in Parma, which he said was comfortable and elegant.[65] In fact the new theatre had not only to be a room for teaching and experimenting, but also to act as a splendid display room for the apparatus. In 1788, describing the ideal display of the cupboard with the machines Volta wrote:

> se saranno ben costrutti, vi si potranno mantenere tutte le macchine lucide e nette, e in istato sempre di servire; e tenendovisi spiegate anche quelle d'Ottica, i Microscopj, ed altri stromenti delicati, che ora stanno chiusi nelle loro cassette, faranno tutt'insieme una più bella e ricca comparsa.[66]

The vast collection, exhibited in a theatrical way, would be a good reason for Volta, and the Austrian rulers, to be proud of the institution. Volta, who spent so much time with the visitors to the cabinet, was well aware of this fact.

Around 1788 the new physics theatre was finally ready. For his courses Volta had at his disposal an amphitheatre (now called Aula Volta) for about 150-200 people. Near the amphitheatre there was a camera obscura, where it was possible to perform optical experiments,[67] while the instruments were displayed in a series of cupboards in a long corridor. At the end of it, a small room was used as a chemical laboratory.

Not only was Volta in contact with Magellan but he also profited from the help of his Milanese friend and colleague Marsilio Landriani (1751-1815) in increasing the equipment of the cabinet. Landriani, who was a physicist and, like Magellan, was well informed about the progress of instrumentation, made several tours (also appointed by the Austrian government), in order to study the scientific and technological developments in various European countries. For example, in 1788 Volta sent Landriani, who was in London, a new list of instruments to purchase for the cabinet. Among them were a Nairne electrical machine, a large camera obscura, a Ramsden sextant, a dynameter, a theodolite, as well as several models of simple

[65] *VE*, II, 646, pp. 294-5.
[66] *VE*, II, 787, p. 431.
[67] Volta was never really interested in optics and probably he hardly used the camera obscura. In fact in 1795 he was accused of neglecting this area of physics. Volta replied to these accusations. He recognised the importance of optics, but he also explained how difficult it was to perform optical experiments for a large audience. In fact the about 200 people who attended his lessons, were far too many for the camera obscura. Optical experiments, Volta insisted, could be profitably performed only for a few, and it would have been impossible to repeat the demonstration several times for small groups of students. The sun, the indispensable source of light at the time, could hardly be constantly available when desired. Nevertheless, in spite of his lack of interest, which he could hardly mask with his explanations, Volta did not forget to increase the quantity of optical instruments in the collection. See *VE*, III, Appendix XXII, "Volta al Magistrato di Governo ed alla Corte. Risposte a varie domande fatte al professore di fisica particolare", pp. 511-43. See in particular pp. 536-43.

machines and several optical and hydraulic instruments. Landriani diligently commissioned the machines from the London makers and, because he was leaving for Holland, asked Tiberius Cavallo (1749-1809) to supervise their realisation.[68] Some of the apparatus arrived in Pavia in 1792. In 1795 Landriani, who was at the time in Vienna, also suggested to Volta the purchase of a model of Kempelen's steam pump.[69] In 1790 Volta, together with his assistant and instrument maker Giuseppe Re, compiled a second inventory[70] of the collection of the cabinet (the first one had been made in 1776 under the supervision of Barletti). This new inventory was probably prepared following the relocation of the collection to the recently built physics theatre This inventory also contains a list of the instruments which had been bought up until 1794, and thus includes the apparatus purchased via Landriani. At this time the items in the cabinets totalled about 400, double the number mentioned by Barletti. The second inventory is more detailed and interesting than Barletti's one. The most important instruments are better described and Volta often mentions where and by whom they were made, and when they were purchased. A series of comments concerning the cabinet and the activities of Re and other local makers are reported at the end of this inventory.

But the equipping of the cabinet could not be completed and again in 1795 Volta continually asked for new grants for instruments: "supplica egli per l'aumento di tal Dote, onde accrescere annualmente con utili provviste il corredo di Fisica; il quale, per ampio e ricco che sia, non è nè sarà mai compito, essendo il campo della Fisica sperimentale, delle invenzioni e delle nuove macchine illimitato".[71]

The last years of the 18th century represented an extremely busy and active period for Volta, and coincided with a period of turmoil for Lombardy. In 1796 the French troops entered Lombardy and Volta welcomed Napoleon in Como. Following an attack against the French army, Pavia was sacked on May 25 but fortunately Re was able to write to Volta saying that the cabinet had sustained very little damage.[72] In 1799, the temporarily restored Austrian government (which had a very short life before the return of the French) fired Volta and all his colleagues at the University. At the end of the same year Volta constructed his first pile, which was described to Joseph Banks of the Royal Society in the famous letter of March 1800. In 1800 Napoleon himself reinstated Volta at the University. Volta was a celebrity, and his scientific and political influence had never been so great. Nevertheless, he did not forget the cabinet and in the last months of 1801, in spite of

[68] *VE*, III, 806, pp. 9-11. Tiberius Cavallo was born in Naples, but he settled in London in 1771. His most important studies concerned electricity, magnetism and the physics of "elastic fluids". He became a fellow of the Royal Society in 1779.
[69] *VE*, III, 1005, p. 254.
[70] See VOLTA and RE (1790-94).
[71] *VE*, III, Appendix XXII, "Volta al Magistrato di Governo ed alla Corte", p. 516.
[72] *VE*, III, 1042, pp. 293-4.

his busy agenda, Volta profited from his stay in Paris to visit the workshop of the celebrated instrument makers Dumotiez,[73] whose apparatus seemed to him very good but also extremely expensive.

It clearly appears from his letters, that since the beginning of the 19th century Volta had been growing more and more tired of Pavia and the University. He would have preferred to continue his studies in Milan for a few months a year. The ageing Volta was missing his family in Como and was trying to retire or at least to greatly reduce his University duties.[74] Finally, in 1804, Pietro Configliachi (1777-1844) officially succeeded Volta to the chair of physics at the University. Nevertheless Volta still worked in Pavia, delivering his courses and, while his stays became less frequent, he continued to show interest in the new instruments. In the first years of the 19th century he often corresponded with Abbot Angelo Bellani (1776-1852). Bellani was a scientist as well as an instrument maker. His research dealt with meteorology, thermometry, and with the phenomena related to evaporation. He became a very skilful glass blower. He greatly improved the construction of thermometers and hydrometers and invented a special radiation thermometer called "lucimetro".

In 1806, in a letter to the director of the state education, Volta, together with his successor Configliachi, asked for a special grant for the physics cabinet to purchase about 20 new pieces of apparatus, (such as a Coulomb balance, a Wedgwood pyrometer, a Borda magnetic circle and an hydraulic ram) which were not yet amongst the instruments in the collection.[75] About a year later Configliachi wrote to his predecessor that a special grant of 2,000 lire had finally been given for the proposed acquisitions. Finally, in 1818 a new inventory was compiled by Configliachi and Volta together.[76] In fact Volta signed it as director of the philosophical faculty of the University. This was the last official appointment which he held in Pavia. The additions to the inventory were also signed by Volta until October 1819, while from the end of 1820 until 1842 the only signature on it was Configliachi's. This inventory was the last written document to state the active, official presence of Volta in the cabinet of Pavia. Up to Volta's last signature, about 600 items were mentioned in the inventory, including, as well as the instruments, some furniture and tools of the cabinet. However, also this inventory was not very accurate. In fact in 1845, a new inventory by the physicist Giuseppe Belli, who at the end of 1842 succeeded Configliachi in Pavia, listed about 250 items, which had

[73] *VE*, IV, Appendix XXVIII, "Diario di Luigi Valentino Brugnatelli", pp. 461-533. See p. 511. The brothers Louis Joseph and Pierre François Dumotiez were instrument makers in Paris from about 1780 until 1815 circa. They proposed several physics instruments. Their two-barrel pneumatic pump became very popular. Their successor was the very famous maker Nicolas Constant Pixii, whose son Hyppolite in 1832 invented one of the very first magneto-electric machines.
[74] See for example: *VE*, IV, 1284, pp. 199-201 and 1307, pp. 231-4.
[75] *VE*, V, 1487 pp. 29-31 and V, 1522, pp. 71-2.
[76] See VOLTA and CONFIGLIACHI (1818-19).

not been mentioned in Volta and Configliachi's inventory. Knowing the maniacal precision which was typical of Belli, we believe that his list is the most detailed. It is curious to see how Volta, even at the very end of his career in Pavia, was still handling the apparatus. In fact, in a note it is possible to see that three instruments (a straw electrometer and two thermometers) had to be erased from the inventory because they had been broken by Volta himself.[77]

4. Italian Instrument Makers Working for Volta

As mentioned above, the importance of the Italian precision and scientific instrument industry was not at all comparable with the same industry in England or in France. Nevertheless, in Pavia as well as in most of the Italian universities and astronomical observatories there were local *meccanici*. "Meccanico" was the Italian term which designated craftsmen who both made and repaired scientific instruments. Furthermore, if they were working in a University they also had to move the apparatus to the lecture room, prepare (or help to prepare) the demonstrations and keep the collection in good condition. A few of them were quite skilful and worked rather well but, unfortunately, as we will see below, they were hardly supported by the local authorities and, most of the time, their activity was more about surviving than prospering. On the other hand, not only was the Italian market fragmented in different states but it was also much smaller and less demanding than the French and the English ones. These two countries had a large colonial market which for various reasons (navigation, exploration, surveying geodesy) could stimulate as well as absorb a much larger production. There are many other reasons which can explain why the production of the Italian makers was qualitatively and quantitatively inferior to that of their foreign homologues in France or England. Due to their very limited impact on the scientific instrument market and their quite low status in the Italian scientific community, very little can be found about their lives and activities. Therefore we think, that it is important to report here some of the biographical information which we were able to find out during our research. Most of this is, in fact, extracted from Volta's correspondence.

Abbot Giuseppe Re (?-1820), who was active during the last quarter of the 18th century and at the beginning of the 19th century, was certainly one of the most valuable and faithful of Volta's collaborators. Giuseppe Re was a "meccanico" as well as the assistant of the physics cabinet.[78] After his arrival in Pavia in 1779, Volta wrote to Firmian:

[77] *Ibid*., see the page related to the year 1819.
[78] About the instruments made by Re, see VOLTA and RE (1790-94) and *VE*, III, Appendix XXII, "Volta al Magistrato di Governo ed alla Corte", pp. 511-6.

> Sono contento che molte cose posso io far costrurre sotto ai miei occhj dall'istesso macchinista Ab. Rè, il quale travaglia alla perfezione tutto fuorché i vetri: Alcune delle belle macchine che si trovano in questo Gabinetto sono state fatte intieramente da lui: ora sta lavorandone alcune.[79]

In October 1780 when Volta travelled to Florence to visit the magnificent scientific cabinets of the Grand Duke of Tuscany, as well as the collection of Lord Copwer, Re accompanied him and made drawings of several pieces of apparatus to be reproduced in Pavia.[80] Later, Copwer himself wrote to Volta asking for a eudiometer made by Re. Re worked alone for a modest amount of money, and during the university summer vacations he profited by constructing a few instruments and pieces of apparatus for various private clients, thus earning some extra money. Volta thought that Re deserved better treatment and also that his activities could be made more profitable for the cabinet by giving him the possibility of training a few apprentices. He therefore complained to Count Firmian:

> Ma quello, che un solo Macchinista può fare è ben poco; e per completare il Gabinetto di Fisica ci vuole ancora molto: avesse almeno l'Ab. Re sotto di sè qualche garzone od allievo; ma le strettezze di casa e di sostanza non gliel' permettono. Costì in Milano si sta meglio d'Artisti in ogni genere, e più particolarmente per la Fisica [...] oh, sarei io pure contento, e si farebbero più grandi cose, se tanti lavorassero per il gabinetto di Pavia! Ma qui non c'è altri che l'Ab. Re.[81]

Barletti was even more enthusiastic than his colleague, and with a certain pride (and probably a bit of exaggeration) stated: "la bella macchina pneumatica fatta fare da me recentemente, e lavorata dal mio macchinista in Pavia, assai superiore in bellezza e perfezione a quelle di Londra".[82]

During the 1780s Volta often tried to convince the authorities of the need to support Re's work by giving him the chance to instruct a few assistants, and by providing him with a larger house. In 1784 for example, when Volta was explaining to Prince Kaunitz his need for a new physics theatre, he proposed to find nearby a new house and a new workshop for his instrument maker. For Volta this new accommodation would have been ideal for several reasons. First, the most fragile instruments could be repaired without carrying them far to Re's house, thus avoiding the transport risk. Second, the workshop of Re, which Volta judged well equipped with tools and excellent lathes, could be viewed as an important section of the

[79] *VE*, I, 322, p. 331. However it seems that by 1780 Re, thanks to the instruction of a barometer maker coming from the region of Como, also learned to make glass instruments such as thermometers and barometers. See *VE*, II, Appendix IX, "Nota di macchine singolari ed anche di lusso", pp. 455-67.
[80] *VE*, II, 406, pp. 8-10.
[81] *VE*, I, 384, p. 410.
[82] See the quotation of Barletti reported in LAGUZZI (1994), p. 54.

cabinet by the many foreign visitors to the collection. And third, with more space and comfort Re could finally have a couple of apprentices.[83] In the 1780s and in the early 1790s Volta repeated his suggestions concerning Re many times. With the opening of the new physics theatre Re's duties were sharply increased. Not only was the number of instruments he had to look after constantly growing but also the hours dedicated to experimental demonstrations had been increased. Volta therefore asked to increase Re's salary, who, by this time was working for 600 lire a year.[84] It is difficult to understand whether Volta's requests were accepted by the government, but his numerous letters dealing with the same topics, make us think that the authorities were not very sensitive about this point. In fact, we believe that Re, who worked in Pavia until the beginning of the 19th century, was never given the opportunity to have apprentices. In the last decade of 18th century, his younger brother Luigi had been working with him without payment, and finally in 1801 Volta suggested to the French rulers to officially hire Luigi as the successor of Giuseppe, whose health and forces were declining.[85]

Giuseppe Re certainly was the most important instrument maker working in Pavia during Volta's time. By the end of the century several dozen instruments made by him were to be found in the cabinet. Unfortunately we know that not all his instruments were signed and that is certainly the case for several electrostatic instruments used and invented by Volta in Pavia. A majority of them are mentioned in the 1790 inventory as "made by Re" but none of the surviving ones bear his name. Some of Re's other mechanical demonstration apparatus (levers and pulleys, demonstration of the wedge, etc.) survive today in Pavia in the Liceo Ugo Foscolo. Of course, they are not precision instruments but they show very good craftsmanship. And even if they are not decorated with the typical red, black and gold painted ornamentation of the many instruments which had been acquired in Paris at the time, their design is strongly reminiscent of Nollet and Sigaud de la Fond's instruments.

Since the time of his professorship in Como, Volta had appreciated the skill of Marco Saruggia, who was "macchinista" at the Brera observatory in Milan. In 1778 Volta unsuccessfully asked the government for an official position at Como for one of Saruggia's best apprentices.[86] Again in 1780, in a letter to Firmian, he explained how he could profitably employ Saruggia (or one of his workers) in Pavia,[87] even if Volta once had to complain about him for his lack of confidence and care in dealing with him.[88] Saruggia, had made several instruments for Volta and for Landriani, and,

[83] *VE*, II, 584a, pp. 217-20.
[84] *VE*, II, 787, pp. 429-37 and III, 871, pp. 80-2.
[85] *VE*, IV, 1165, pp. 38-9.
[86] *VE*, I, 242, pp. 232-3.
[87] *VE*, I, 368, pp. 394-5.
[88] *VE*, I, 267, p. 264.

unlike Re, was also an able glass blower. In the Pavia collection were several artefacts made by Saruggia: glass apparatus, such as thermometers, barometers, eudiometers, a battery of Leyden jars, an electrostatic machine with a disk made of sulphur and a Papin digestor.

One of the biggest problems in Pavia was to find a good glass instrument makers. It is well known that between the second half of the 18th century and the first decades of the19th century the region surrounding Lake Como had been the cradle of dozens of glass blowers, who during the winter season spent several months travelling in Europe, manufacturing and selling their thermometers, barometers and glass instruments.[89] It is not clear why so many craftsmen, who specialised in this very particular activity came from this area, where, unlike Venice, no particular tradition of glass making and glass blowing existed. Nevertheless Antonio Cetti (1762-1835) belonged to this community of Lombard peripatetic instrument makers.[90] In 1790 and 1791 Cetti spent several weeks in Pavia, where he successfully worked for Volta, Barletti, Spallanzani and other professors of chemistry, natural history and anatomy. Here, Cetti made barometers, thermometers, laboratory siphons and fountains as well as many other instruments. Moreover, Cetti supervised various orders of instruments which had to be made in Venice.[91] Volta and his colleagues were extremely satisfied with Cetti's work and they unanimously asked the government to hire him. Cetti was prepared to stay in Pavia for a modest salary (500-600 lire circa). He could work for the University for eight months a year, while for the rest of the time he could work independently. Furthermore, at that time the above-mentioned Marco Saruggia had died, and even in Milan it was almost impossible to find a good barometer maker.[92] Again in the spring of 1791 Volta repeated his request to the government and pointed out that, without a steady salary Cetti would prefer to continue his career as a peripatetic instrument maker, visiting Germany, France and Switzerland where he could earn more money.[93] Volta's hopes for Cetti were not fulfilled and finally the barometer maker left Italy. But Cetti's career was just beginning. In fact it is interesting to note that an Antonio Cetti (almost certainly the same) reappeared in Copenhagen in 1797. There, he manufactured glass instruments in the winter while in the summer he showed his glass-making art in an amusement park not far from the town. By displaying a wax cabinet, trained birds and by performing public physical and chemical experiments, Cetti made money and he became a well known public figure. His son became a famous singer at the Royal Opera in Copenhagen.[94]

[89] See LUCATI (1954).
[90] Cetti was a common name and Banfield counts more than a dozen different Cettis, who were making, selling or retailing glass apparatus in London. See BANFIELD (1993) and BANFIELD (1991).
[91] *VE*, III, 870, p. 80.
[92] *VE*, III, 862, pp. 71-2.
[93] *VE*, III, 886, pp. 103-4.
[94] ANDERSEN (1991).

Another maker, who was often mentioned by Volta with admiration was Giuseppe Megele (1740-1816). After an apprenticeship in Vienna, in 1773 Megele became the "first mechanic" of the Brera astronomical observatory, which was one of the most important scientific institutions in Milan. Apart from a couple of years, which he spent in Vienna (1792-1794) because of various conflicts with the Brera astronomers, he held this position until his death. Megele was certainly one of the few "precision makers" in Lombardy. Several instruments made by him survive in Milan, and Megele's work in Pavia is represented by a regulator clock.[95]

A few other local makers appear in Volta's letters and inventories but unfortunately we do not know much about them. Around 1780, the monk Francesco from the monastery of Belgioioso (a small village near Pavia) made a simple pyrometer as well as a compound pendulum for the physics cabinet. The former instrument, which is signed, still survives in the collection.

Canon Giovanni Francesco Fromond from Cremona was working in Milan for the astronomical observatory of Brera. He specialised in optical apparatus and he also supplied a few instruments for the cabinet of Pavia. For it he manufactured a Boscovich heliostat, a series of lenses, as well as a beautiful and still surviving (though incomplete) box of glass prisms in various shapes and colours.

Finally, in spite of the problems encountered by Volta in having his instruments made in Pavia, the activity of the makers collaborating with the cabinet, was at least partially able to supply the local market of simple apparatus. This fact is confirmed by a letter that Barletti wrote to the authorities in 1788: "negli anni scorsi sono sempre partite da Pavia parecchie casse di macchine fatte su mia commissione, e sotto la mia direzione per vari professori e dilettanti di fisica miei corrispondenti".[96]

5. Volta's Role in the Development of the Physics Cabinet

Volta was a typical member of the cosmopolitan scientific community of his time and as such he was well aware of the research which was being carried out in Europe. He also corresponded with almost all the leading members of the scientific establishment. His long and repeated trips to the most important European cities, his close friendship with several scientists, his natural curiosity for the phenomena of nature, his experimental skills as well as the respect and the celebrity he gained for his discoveries, all this factors contributed to putting Volta in a particularly favourable position for building up a very important physics cabinet in Pavia.

On the other hand, for the Austrian government the newly reformed University of Pavia had to be one of the cultural centres of excellence in the empire. Therefore it

[95] See MIOTTO and TAGLIAFERRI and TUCCI (1989). Sometimes the name of this maker is wrongly written as Meghele.
[96] See the quotation of Barletti reported in LAGUZZI (1994), p. 54.

also had an important political meaning and thus the good name of the institution was a major concern for the Austrian rulers. Furthermore, Volta was one of the most important and best-known scientists working in Pavia, and as such he deserved a well equipped cabinet. The cabinet in fact was more than a place where Volta could experiment and teach, it was also a museum, a showroom and the attractive theatre where the glitter of glass and brass had to impress the learned and distinguished visitors. Volta knew that very well and in 1780 wrote:

> ma anche i forastieri, i quali son già molti, che mossi e invitati dalla celebrità di questa Università si portano a visitarla, vedranno con quella stessa soddisfazione e sorpresa il Gabinetto di Fisica, e lo andranno vantando dappertutto, con cui già vedono, lodano e ammirano il Giardino Botanico, il Laboratorio Chimico e il Museo di Storia Naturale.[97]

An important library, a large natural history collection, and a well equipped scientific cabinet were in fact the most spectacular show windows of a cultural institution. For all the above mentioned reasons it is not surprising that the Austrian government willingly fulfilled Volta's request for instruments for his cabinet. As we have showed, not only were his suggestions usually promptly accepted but Volta was also encouraged in his acquisition policy.

If Volta could not complain about the possibility of constantly increasing the physics collection, things were quite different as far as his efforts went for improving the local production of instruments. Since his stay in Como, Volta often complained to Firmian about the lack of specialised makers "in Como non v'ha pur chi travagli una vite in ottone, in avorio, in legno; chi lavori le lenti; chi faccia astucci; non v'ha alcun Ebanista".[98] And also later, in Pavia, the situation was not really satisfactory. The presence of the maker Giuseppe Re was not enough for supplying the instruments and for fulfilling the cabinet duties (preparation of experiments, repair of apparatus, etc.). In vain Volta sought for a better salary and better accommodation for Re as well as the possibility of hiring a couple of apprentices. In fact, despite his several requests concerning not only Re but also Marco Saruggia, and even Antonio Cetti, it appears that very little was done by the Austrian rulers, who seemed to be quite deaf to these demands. Volta's efforts to explain the practical and economic advantages of having a few more makers in Pavia, and of making more instruments locally, were not really successful. For example Re was not given larger accommodation or a better workshop, which he had to provide for himself, and the proposal of hiring Cetti was never accepted. Count Luigi Lambertenghi, who wrote Volta, had been clear about the situation since 1778: "il me paroit impossible à esperer qu'on vous paye un artiste pour la Physique".[99]

[97] *VE*, II, Appendix IX, "Nota di macchine singolari ed anche di lusso", pp. 455-67, see p. 467.
[98] *VE*, I, 242, p. 233.
[99] *VE*, I, 274, p. 277.

Perhaps this situation is not too difficult to understand. There would have been little advantage for the Austrian government and for Lombardy to have more instrument makers in Pavia or even in Milan. Nobody could really envisage developing the local instrument-making industry to such a degree that it would seriously compete with foreign makers. From a technical and practical point of view English makers were several decades ahead of the Italians and the gap could not have been filled even with a large economic effort. Furthermore, the saving of a few thousand lire by acquiring instruments locally and not abroad would have been negligible, and would have been more or less annihilated by paying the salaries for new makers and apprentices. Moreover, the effect of this investment, if there were one, would have been quite slow, while the money used for buying instruments abroad could be immediately converted into brass and glass. Finally, the quality and renown of a scientific instrument collection, was largely due to the quality of their instruments and thus to their provenance. It is obvious that the names of Martin, Dollond, Ramsden, Adams, Nairne, etc. meant excellence, and their instruments certainly gave more renown to a collection than the names of the local craftsmen (even if good). For the above-mentioned reasons it seems quite understandable that if the Austrian government proved to be generous by spending large sums of money for enriching the collection, it was quite resistant when Volta tried to increase the number of local makers or to improve their facilities.

How did Volta choose the instruments to buy and how did the collection grow during his time in Pavia? As we can see from the inventories, from a purely statistical point of view Volta greatly increased the number of instruments in the University, which grew from about 200 in 1775 to about 600 when he finally left Pavia. But that of course is not the most interesting point. More important is to try to analyse the change in the typology of the collection.

During Volta's years in Pavia, several branches of physics (of the "fisica particolare" which Volta had to teach), which were almost purely qualitative and phenomenological, slowly became more quantitative and mathematized. (In fact, Volta also contributed, with his comparable electrometer, to starting this transformation in the field of electricity). The Pavia collection under the direction of Volta reflects the same kind of evolution. The amount of demonstration and teaching apparatus remains very significant, but an ever-increasing number of measuring and research instruments were added to the collection. Electrometers and a Coulomb balance, precision thermometers and barometers, hydrometers, analytical balances, goniometers are among the precision instruments acquired by Volta. This evolution was certainly common to several others European institution of the same

kind. However, Volta was constantly able to update his cabinet, leaving Pavia with a modern, well-equipped cabinet, which represented the state of the art at the time.[100]

Finally, in the first decades of the 19th century, the physics cabinet was considered a tourist attraction for distinguished travellers visiting the University. In 1819 M. Malaspina dedicated a couple of pages to it in his *Guida di Pavia*.[101]

6. The Instruments of Volta's Physics Cabinet Surviving in the Museum for the History of the University of Pavia

For a long time, only a few of Volta's electrical instruments which had not been destroyed by the 1899 fire, were considered Volta's relics, and thus thought to deserve a special place in the Museum for the History of the University of Pavia. But in recent years, a careful study of the museum collection allowed this historical mistake to be corrected and a better understanding began of what Volta had at his disposal in his cabinet. Unfortunately, many instruments were destroyed, damaged or discarded during the 19th and 20th centuries. Furthermore, until a couple of decades ago, almost nobody cared about the old tools of science. Not old enough to be considered antiques (such as a Renaissance astrolabe), useless for research and too old fashioned for "modern" teaching, they were simply abandoned in a humid cellar or destroyed. Other instruments were inadvertently broken by the professors and their assistants (Volta himself admitted to have smashed a Rumford thermometer). It is true that, at least until the early decades of the 20th century, many demonstration instruments, which had been proposed in the 18th or 19th centuries, were still in use: that was the case for the Atwood machine. But unfortunately the original, which had been sent from London to Pavia by Magellan was replaced by a more modern version, made of cast iron by the Italian firm Tecnomasio, around 1870. So the third Atwood machine ever made had disappeared! And where are the large (and probably beautiful) orreries made by Adams, which disappeared from the collection long ago? Were they stolen, destroyed or sold somewhere? The fate of such collections is often sad, and many precious and interesting pieces of apparatus have been eliminated when they were not yet considered part of an important, valuable historical heritage. However a good number of instruments from Volta's time have been rediscovered. Apart, of course, from the instruments themselves, our most important information sources were Volta's correspondence, as well as the three surviving inventories of the collection, which we mentioned above. Further help came from the study of 18th century illustrated physics textbooks as well as

[100] About some of the most interesting collections of physics apparatus of the time, see BOS (1968); BRENNI (1993); DE CLERCQ (1997); DE SMET (1991); DUBOIS (1898); GUNTHER (1923); MORTON and WESS (1993); LEVERE and TURNER (1973).
[101] MALASPINA DI SANNAZARO (1819).

from the catalogues of large surviving collections, which often preserve the same kind of apparatus as the Pavia cabinet. It was not always an easy task to determine a correspondence between the surviving apparatus and the old inventory descriptions. These are not always very clear or detailed and they often generate several doubts. Furthermore several items, which were not considered particularly important or special, were just mentioned as "group" or "series" of instruments. It was particularly difficult to determine the date of several objects, which, for many decades were made without any major change of design or material. Leyden jars, glass apparatus, simple vessels, a few optical instruments such as lenses and mirrors, etc., especially when they do not bear any kind of signature, are very difficult to date with precision. Finally, our list includes all the instruments which certainly or with "reasonable certitude" were acquired for the physical cabinet before 1819. These instruments are today preserved in the Museo per la Storia dell'Università di Pavia (see the web-site of the museum: http://ppp.unipv.it/Museo/museo.htm).

The list below gives the following information: "Invent." = modern inventory number of the apparatus; "Instrument" = name of the instrument; "Maker" = name of the maker, if his signature is on the instrument ("?" near the name when the instrument is not signed but the maker is almost certainly known); "1776", "1790", "1818" = dates of the inventories ("*" indicates in which of the inventories the instrument appears for the first time).

Invent.	**Instrument**	**Maker**		**1776**	**1790**	**1818**
A 7	Pendulum clock	Megele, Milan			*	
B 20	Standard kilogram	Fortin, Paris				*
B 7	Standard metre	Megele, Milan				*
B 8	Standard metre, with Parisian foot and Milanese arm					*
B 21	Hydrostatic balance	Haas, London			*	
C 4	Guinea and feather apparatus					*
C 9	Triple lever				*	
D 16	Communicating vessels					*
D 4	Magic funnel				*	
D 5	Tantalus beaker				*	
D 6	Immersion elevating pump (model)	Haas, London	?		*	
D 7	Suction and elevating pump (model)	Hass, London			*	
D 8	Suction and force pump (model)	Haas, London			*	
E 1	Ear trumpet					*

E 2	Ear trumpet					*
E 23	Hase's speaking trumpet				*	
E 17	Clockwork-driven bell in vacuum				*	
E 16	Bell in vacuum					*
F 17	Syringe pump with weight	Martin, London	?	*		
F 28	Magdeburg hemispheres	Martin, London	?	*		
F 3	Siphon barometer					*
F 35	Clockwork-driven flint-lock in vacuum	Sigaud, Paris	?		*	
F 38	Spherical bottle for pneumatic pump					*
F 7	Mariotte's tube	Sigaud, Paris	?		*	
N 228	Hygroscopic bunch of artificial flowers					*
G 1	Pyrometer	F. da Belgioioso			*	
G 10	Mercury thermometer	Bellani, Monza				*
G 11	Bellani's "ghiacciometro"	Bellani, Monza				*
G 16	Leslie's thermoscope					*
G 12	Alcohol thermometers					*
G 13	Alcohol thermometers					*
G 14	Alcohol thermometers					*
G 24	Alcohol thermometers					*
G 24c	Alcohol thermometer					*
G 09	Alcohol thermometer (3 scales)	Bellani, Monza				*
G 15	Mercury thermometer					*
G 17	Mercury thermometer					*
G 18	Mercury thermometer	Bellani, Monza				*
G 22	Mercury thermometer					*
G 23	Mercury thermometer					*
G 26	Dial thermometer (incomplete)	Bellani, Monza				*
G 27	Floating thermometer				*	
G 28	Floating beads thermometer					*
G 03	Regnier's metallic thermometer					*
G 21	Thermometrograph (maximum and minimum thermometer)	Bellani, Monza				*
G 37	Laplace and Lavoisier's calorimeter					*
G 55	Papin's digestor					*
G 56	Jet car	Haas, London			*	
G 06	Set of compensating pendulums and bimetallic strip				*	

G 67	Concave metallic mirrors				*	
G 68	Concave wooden mirrors					*
G 71	Leslie's photometer					*
G 82	Board for spiral thermometer					*
H 6	Plane metallic mirrors					*
H 8	Cylindrical mirror for anamorphosis	Selva, Venice	?	*		
H 9	Curved metallic mirror					*
H 98	Concave glass mirror					*
H 7	Concave-convex metallic mirror					*
H 11	Concave glass mirror with stand					*
H 13	Concave-convex metallic mirror with stand					*
H 14	Concave-convex metallic mirror with stand					*
H 19	Wollaston's goniometer	Dumotiez, Paris				*
H 40	Lens with stand (biconvex)					*
H 41	Lens with stand (biconvex)					*
H 42	Lens with stand (biconvex)				*	
H 84	Lens with stand (biconvex)				*	
H 52	'sGravesande optical box for refraction				*	
H 22	Prism (equilateral) with stand	Selva, Venice	?	*		
H 24	Prism (equilateral) with stand					*
H 25	Liquid prism					*
H 47	Triple prism					*
H 27	Set of seven mirrors with stand					*
H 29	Box with optical glasses	Fromond, Milan			*	
H 53	Solar microscope	Martin, London			*	
H 55	Lucernal microscope	Adams, London			*	
H 54	Compound microscope	Adams, London			*	
H 61	Gregorian telescope	Dollond, London				*
H 62	Gregorian telescope	Selva, Venice	?	*		
H 67	Polariscope					*
I 7	Octant	Dollond, London				*
I 36	Declination compass	Brander, Augsb.			*	
M 1	Spherical loadstone			*		
M 10	Spherical loadstone with stand					*
M 9	Spherical loadstone with stand					*
M 2	Armoured loadstone with stand				*	
M 3	Loadstone with stand			*		

M 5	Horseshoe magnet (compound)				*	
M 6	Rectangular magnet (Knight type)					*
M 7	Rectilinear magnet (compound)					*
M 8	Rectilinear magnet (compound)					*
N 11	Electrostatic machine (Nairne pattern)				*	
N 155	Volta's electrophorus					*
N 2	Spherical conductor					*
N 206	Volta's straw electrometers	Re, Pavia	?		*	
N 206d	Volta's straw electrometer	Re, Pavia	?		*	
N 206e	Straw electrometer					*
N 207	Volta's condenser electrometer	Re, Pavia	?		*	
N 208	Eudiometers					*
N 209	Eudiometer				*	
N 210	Volta's pistol				*	
N 212	Aurora tube				*	*
N 202	Plate condenser with stand					*
N 223	Franklin's squares	Re, Pavia	?		*	
N 225	Sealing-lack painted glass plates					*
N 213	Leyden jar (decorated)					*
N 24	Leyden jars (pear-shaped battery)				*	
N 240	Leyden jars (battery)					*
N 26	Leyden jars (battery)					*
N 27	Leyden jars (cylindrical)				*	
N 28	Leyden jars (rectangular section)				*	
N 29	Leyden jar (square section)				*	
N 30	Leyden jar					*
N 32	Leyden jar (with two electrodes)					*
N 33	Leyden jar (pear shaped)					*
N 6	Dischargers					*
N 214	Flicker tube					*
N 216	Electric mortar					*
N 217	Tinfoil covered wooden disks					*
N 218	Tinfoil covered wooden disks					*
N 219	Variable capacity plate condenser					*
N 221	Tinfoil covered wooden sphere					*

N 222	Tinfoil covered wooden stick					*
N 230	Electric fishes					*
N 227	Disk of pewter				*	
N 35	Lane's electrometer (incomplete)					*
N 45	Electrometer with micrometer					*
N 229	Zamboni's dry pile					*
N 56	Wollaston's pile					*
N 9	Sand tubes vitrified by lightning					*

The following set of instruments, originally belonging to the cabinet of the University, is now preserved in the collection of the Liceo Classico "Ugo Foscolo" in Pavia. Most of the pieces are mechanical and demonstration apparatus acquired from Sigaud de la Fond or made by Giuseppe Re. These instruments were probably removed from the University collection in the 1850s. In fact, at this time, they were given to the cabinet of the newly founded Liceo, which also houses a very fine collection of 19th-century instruments.

Instrument	**Maker**		**1776**	**1790**	**1818**
Inclined plane				*	
Wedge demonstration	Re, Pavia			*	
Gear with endless screw on stand	Sigaud, Paris	?		*	
Balance apparatus		?		*	
Pulley and balance beam apparatus	Sigaud, Paris	?		*	
Stand with pulleys	Re, Pavia			*	
Pulley and lever	Francalancia, Turin			*	
Parabolic trajectory instrument				*	
Cycloidal, circular and rectilinear track	Sigaud, Paris	?		*	
Apparatus for the composition of two movements				*	
Falling apparatus for the angle of reflection	Sigaud, Paris	?		*	
Paddles apparatus for the resistance of the air	Re, Pavia	?		*	
Double pendulum apparatus	Sigaud, Paris	?		*	
Intermittent fountain	Sigaud, Paris	?		*	
Suction and elevation pump	Sigaud, Paris	?		*	
Suction and force pump	Sigaud, Paris	?		*	
Suction and force pump	Sigaud, Paris	?		*	

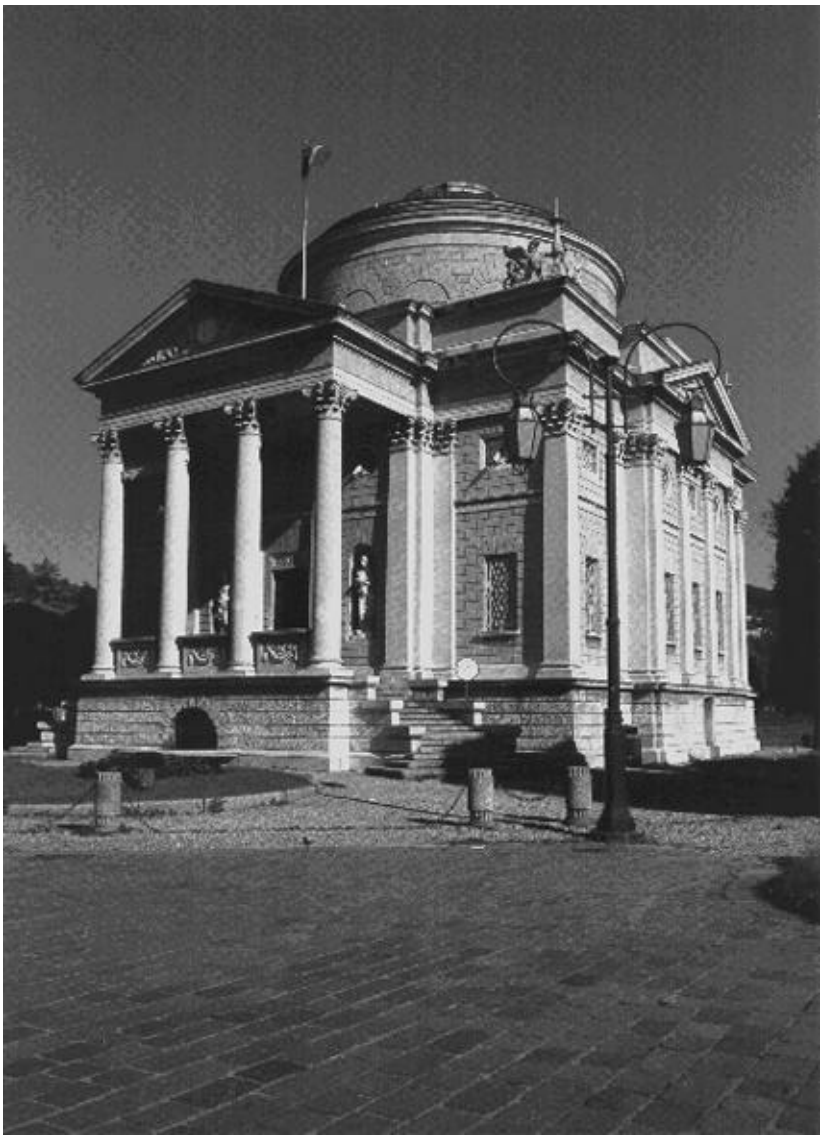

Figure 1 Volta's temple in Como (courtesy Ugo Molteni).

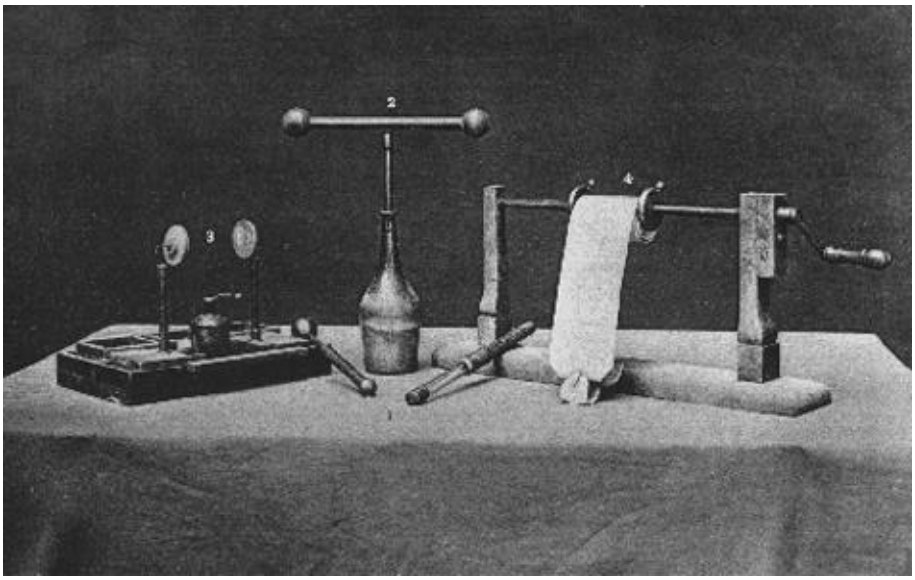

Figure 2 Volta's relics, in a photograph from the turn of the century (from *VO*, IV, p. 120).

Figure 3 The reconstruction of Volta's physics cabinet (courtesy MSUPV).

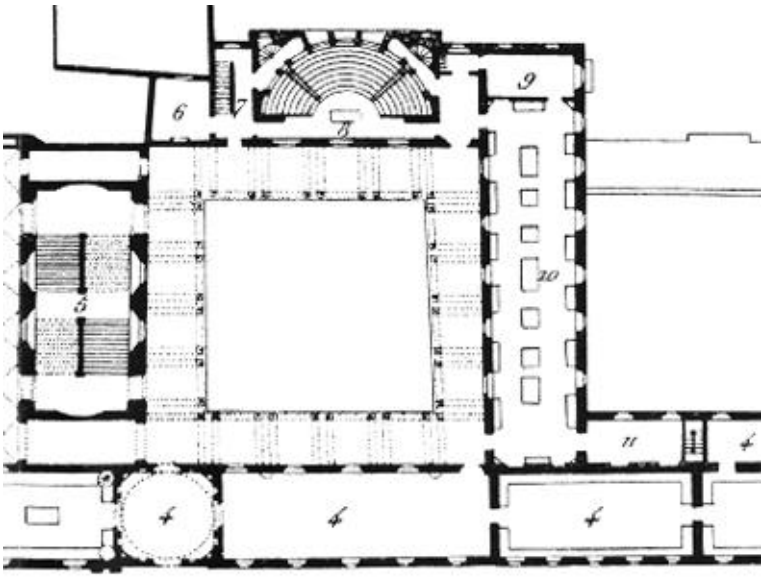

Figure 4 Map indicating Volta's physics theatre (8), the camera obscura (9), the physics cabinet (10) and the physics laboratory (11) (from VACCARI (1982), p. 269).

Figure 5 Volta's physics theatre (courtesy Università di Pavia).

Prospetto
Delle principali Macchine
di Fisica, esistenti nel Gabinetto
della R. Università di Pavia
alla fine dell'anno Scolastico
1790.

Figure 6 Front page of the 1790 inventory of the physics collection (courtesy ASM).

Nota
Dal 1° Luglio 1818 a tutto l'Ottobre 1819.
1. Un Elettrometro a pagliette rotto dal C. Volta
2. Un Termometro con scala di metallo idem
3. Un Termometrografo di Six idem.
A. Volta

Figure 7 Page of the 1818 inventory indicating that Volta still used (and broke!) instruments from the collection (courtesy ASPV).

Figure 8 Magnet donated to Volta in 1781 (courtesy MSUPV).

Figure 9 Adams microscope (courtesy MSUPV).

Figure 10 Sigaud de la Fond's mechanical demonstration apparatus (courtesy Liceo "Ugo Foscolo", Pavia).

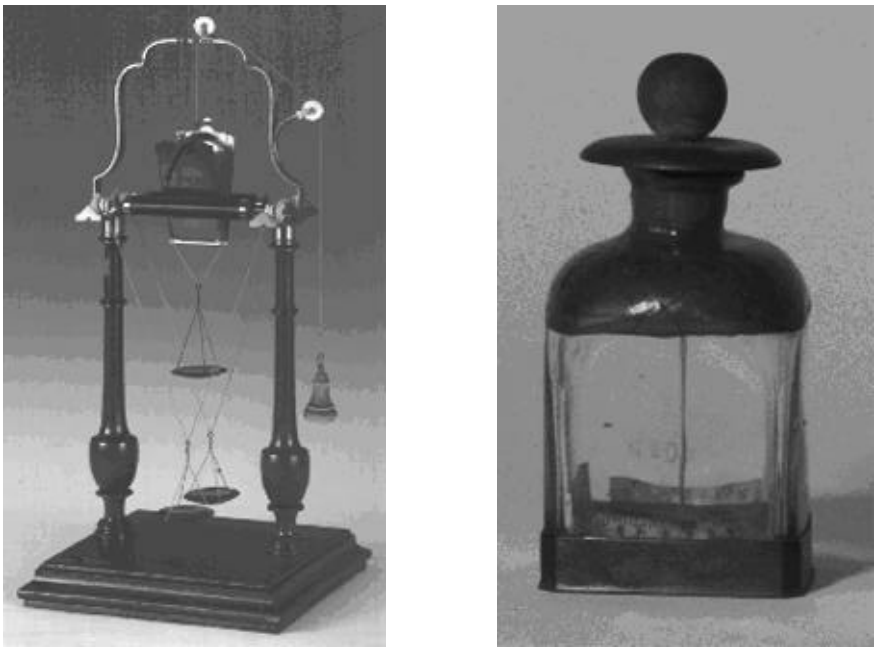

Figure 11 Re's wedge demonstration and straw electrometer probably made by him (courtesy Liceo "Ugo Foscolo" and MSUPV).

Figure 12 Fromond's optical kit (courtesy MSUPV).

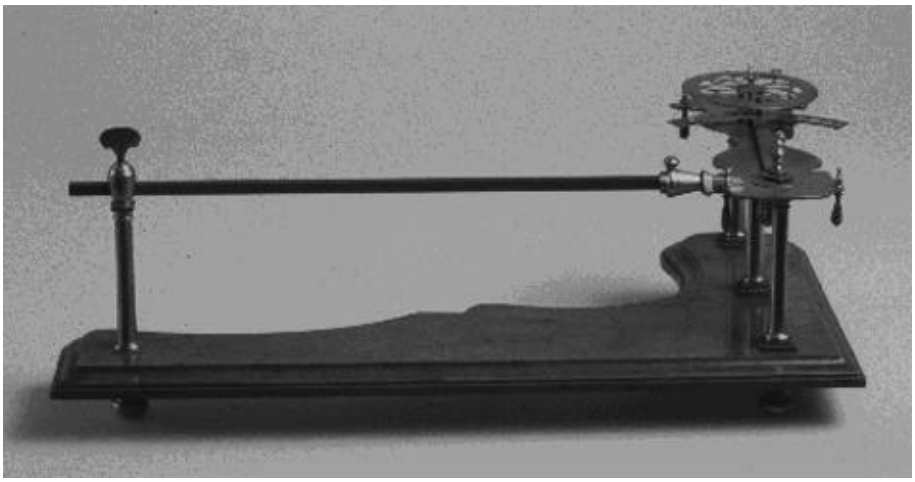

Figure 13 Francesco da Belgioioso's pyrometer (courtesy MSUPV).

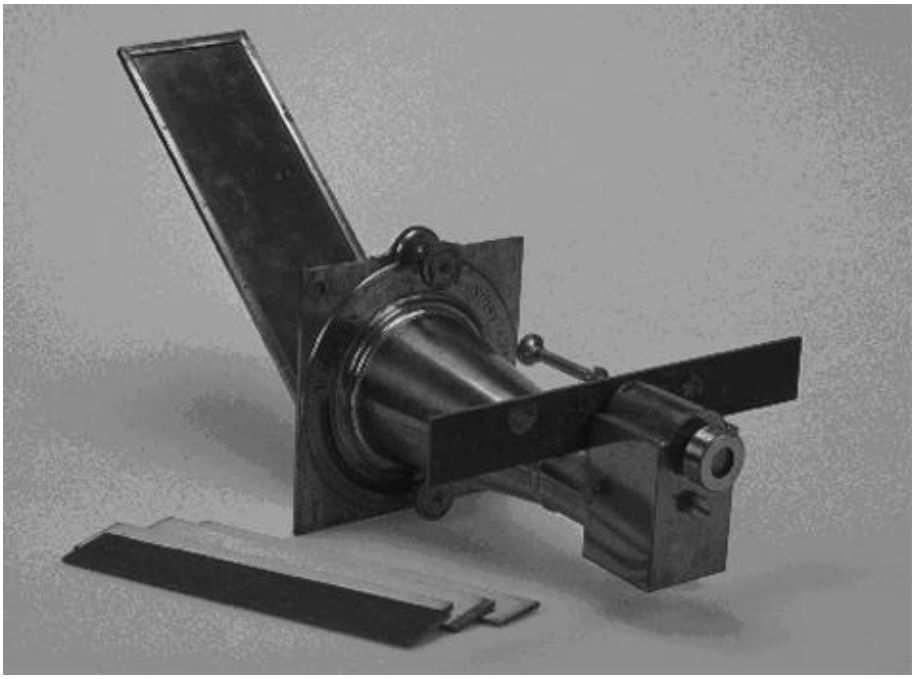

Figure 14 Martin's solar microscope (courtesy MSUPV).

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